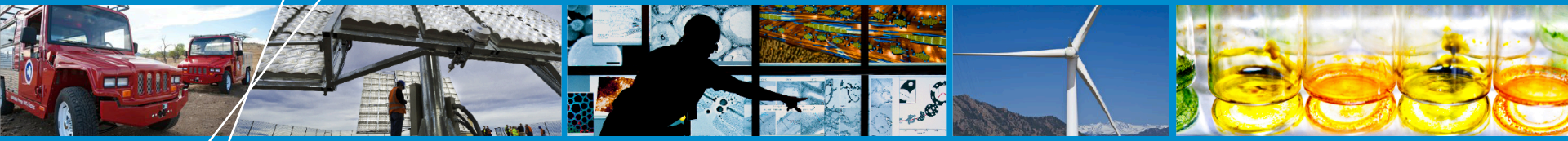
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Costs of Integrating Renewable Energy into the Electric Grid



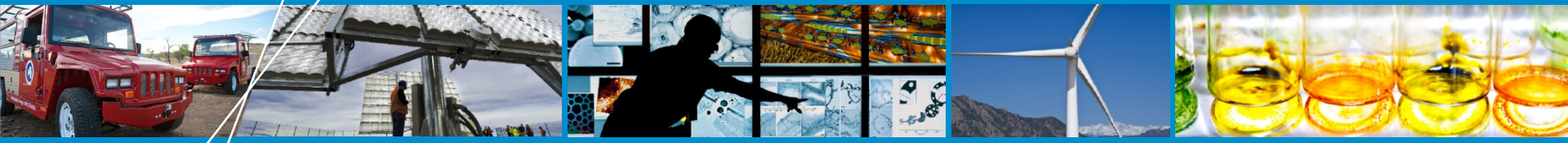
Kevin Porter, Aaron Bloom, and Michael Milligan

Feb. 20, 2013

Housekeeping Items

- **Listen-only mode**
- **Webinar will be recorded**
- **Audio Mode**
  - Use mic and speakers
  - Use telephone: phone # will be displayed and audio PIN
- **Q & A session**
  - Questions box showing on your screen

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



A Review of Variable Generation Integration Charges in the United States

Kevin Porter, Exeter Associates Inc.

Introduction

- The expected growth of wind and solar generation in the United States suggests that local and regional power grids will be operated in a somewhat different manner because of increased variability and uncertainty.
- Some balancing authorities have attempted to determine an "integration cost" to account for these changes to their operating practices.

Forthcoming Report on Integration Costs

- **The report will:**
  - Review the balancing authorities that have calculated variable generation integration charges
  - Broadly compare and contrast the methodologies used to determine integration charges.
- **This report will be published in the very near future.**

Companies in Report

- This report profiles 12 balancing authorities that have taken some action to account for variable generation impacts on their systems.
- Seven impose integration charges on wind and/or solar generation; and six incorporate estimated integration costs in their resource planning, competitive solicitations for generation, or both (PacifiCorp).
- Other than Westar, all the balancing authorities profiled are located in the Western Electricity Coordinating Council.

Two Means of Integration Costs

- Directly charge wind and solar generators for integration charges
- Add expected integration charges to projected costs of wind and solar in integrated resource plans or competitive solicitations for generation

Integration Charges by Technology

- All 12 balancing authorities estimate integration charges for wind
- Three estimate such charges for solar

Report Findings

- Integration studies in support of variable generation integration charges are at an early stage and are more art than science.
- The balancing authorities profiled in this report define and measure integration costs differently.
- Differences include, but are not limited to, study methodology, assumptions, reserve definitions, tools and methods, and data collected and used.

Differences in Determination of Integration Rates

- **Limited use of multiple scenarios other than varying levels of wind or solar generation**
- **Use of different tools**
  - Optimization models
  - Hydro-simulation models
  - Capital expansion models
  - Unit commitment or dispatch model that may be off-the-shelf or developed internally
  - Combinations of the above

Differences in Determination of Integration Rates

- **Different methodologies for estimating the integration impacts of wind and solar**
  - Wind/solar versus flat block
  - Wind/solar versus ideal generator
  - Load versus net load

Final Thoughts

- There is no single generally accepted methodology to calculate variable generation integration costs.
- The art of estimating variable generation integration costs is evolving.
- There is disagreement within the industry about the methodology that should be used.

Contact Information

Kevin Porter

Exeter Associates Inc.

10480 Little Patuxent Parkway, Suite 300

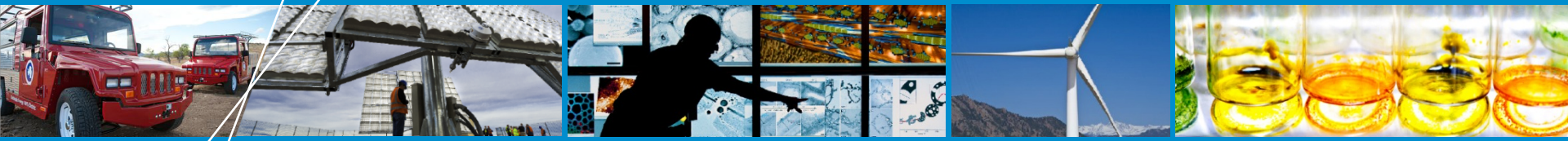
Columbia, MD 21044

410-992-7500

410-992-3445 fax

kporter@exeterassociates.com

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



FERC Order No. 764

Aaron Bloom, NREL

Three Components

- **Intra-hour scheduling**
  - Requirement
- **Forecasting**
  - Conditional
- **Differentiated ancillary services rates**
  - Guidance

What Is a VER?

- **Variable energy resource**
  - Generally understood to be wind and solar, but:

    "Variable Energy Resource shall mean a device for the production of electricity that is characterized by an energy source that: (1) is renewable, (2) cannot be stored by the facility owner or operator, and (3) has variability the is beyond the control of the facility owner or operator."
- **Energy source**
  - Defined by variability of input, not output
  - Applies to wind and solar with storage
  - Could apply to tidal, wave, run-of-river, and others

Intra-Hour Scheduling

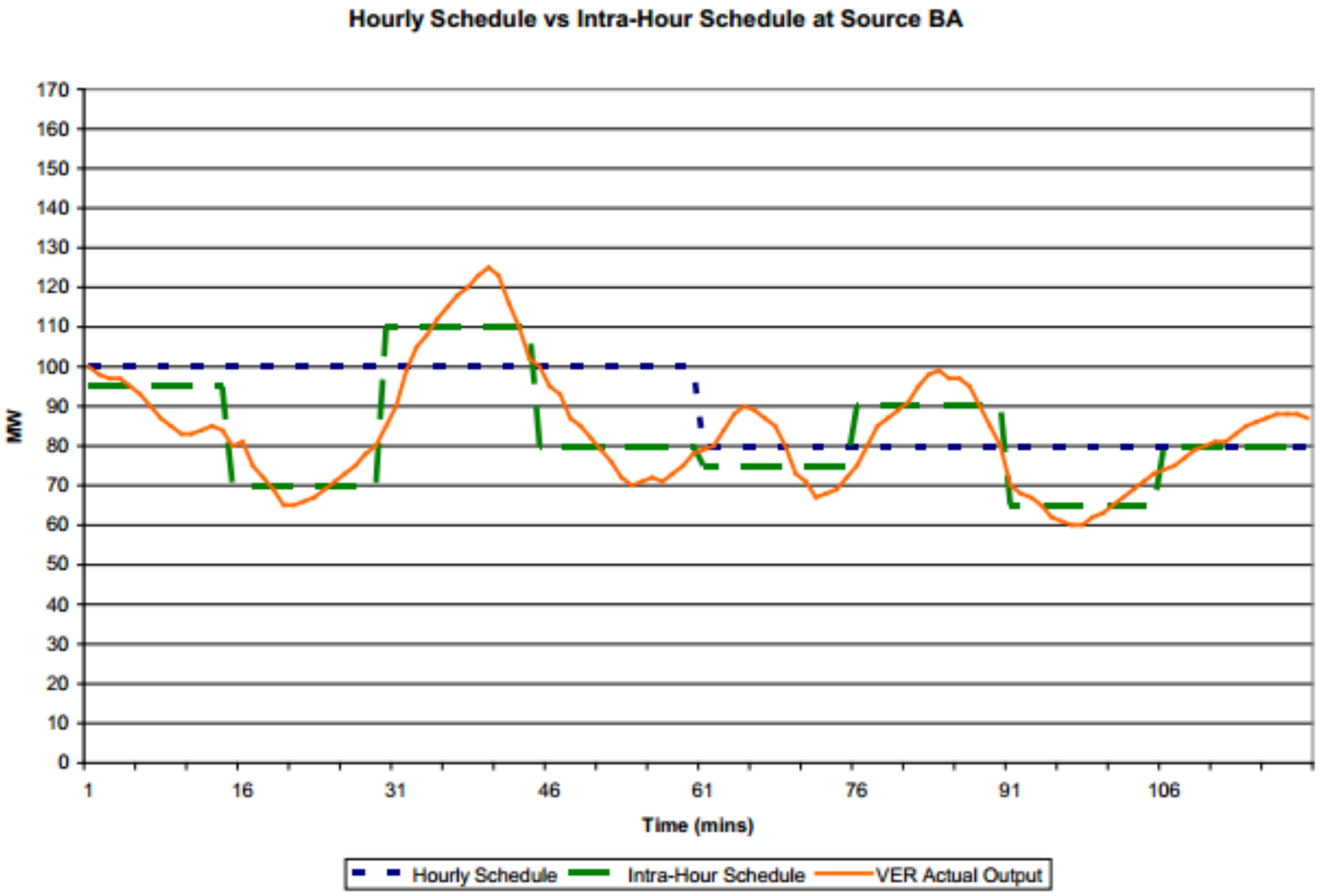
13.8 Scheduling of Firm Point-To-Point Transmission Service:

Schedules for the Transmission Customer's Firm Point-To-Point Transmission Service must be submitted to the Transmission Provider no later than 10:00 a.m. [or a reasonable time that is generally accepted in the region and is consistently adhered to by the Transmission Provider] of the day prior to commencement of such service. Schedules submitted after 10:00 a.m. will be accommodated, if practicable. Hour-to-hour and intra-hour (four intervals consisting of fifteen-minute schedules) schedules of any capacity and energy that is to be delivered must be stated in increments of 1,000 kW per hour [or a reasonable increment that is generally accepted in the region and is consistently adhered to by the Transmission Provider].

Intra-Hour Scheduling

- **All transmission customers have the *option* to schedule transmission at 15-minute intervals.**
  - Who might use it?
    - Transmission customer with forced outage
    - Load
    - VERs

Why Are They Doing This?



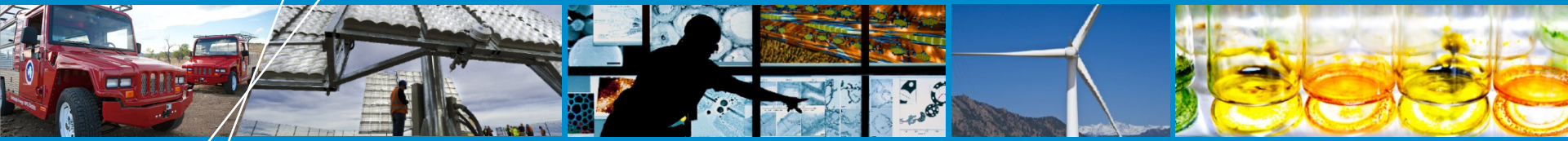
Intra-Hour Scheduling

- **Does it have to be 15 minutes?**
  No, but alternatives must:
  - Be consistent or superior to 15 minutes
  - Demonstrate how they mitigate Schedule 9 generator imbalance charges
  - Show consistency with other scheduling practices in their region.

Scheduling Versus Dispatch

- **Order No. 764 is all about transmission scheduling.**
- **It does not require subhourly dispatch or optimization.**
  - Not a bad idea anyway ;)

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



Forecasting

Power Production Forecasting

- **Conditional requirement**
  - VERs must provide meteorological and forced outage data to their transmission provider *if* the transmission provider is doing forecasting.
  - The transmission provider is only required to do forecasting *if* it is assigning differentiated rates for generator imbalance service.
- **Applicability**
  - New interconnection customers that are VERs

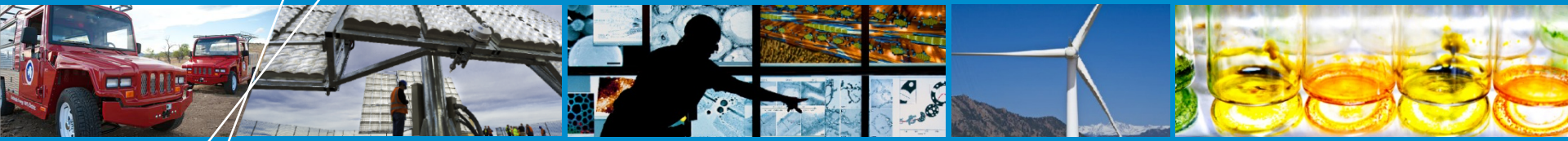
Power Production Forecasting

- **Commission rationale**
  - Forecasting improves situational awareness and thus reliability.
  - Forecasting allows for more efficient unit commitment, dispatch, and transmission operation.
  - Forecasting reduces ancillary service charges.
  - FERC tariff requirements did not allow transmission providers to request forecast-relevant data.

Power Production Forecasting

- **Data**
  - Outlined in Article 8.4 of *Pro Forma* Large Generator Interconnection Agreement
  - Data requirements are intentionally broad to allow for different forecasting techniques
  - Generally requires meteorological and forced outage reporting
  - Transmission provider must show proposed requirements are commensurate with power production forecasting employed by the transmission provider

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



Generator Imbalance Service

Generator Imbalance Service

- **The notice of proposed rulemaking originally included a *pro forma* Schedule 10 for generator imbalance service.**
- **The final rule did *not* include a standard Schedule 10.**

Generator Imbalance Service

- **Yippie! No more integration rates!**
  - Not exactly.
  - The commission opted to continue evaluating new ancillary service schedules on a case-by-case basis.
  - This does not exonerate the transmission provider from its obligation to maintain sufficient capacity to provide generator imbalance service under Schedule 9.

Generator Imbalance Service

Guidance

1. Operational similarities
   - Allocation must relate to operational characteristics.
2. Justification
   - Must justify differentiation.
3. Diversity
   - Transmission provider must consider diversity benefits of class of resources.
4. Historical basis
   - Must be rigorous to reflect actual system operations.
5. Sub-hourly scheduling
   - Does shorter scheduling obviate the need for differentiated rates?
6. Forecasting
   - Forecasting impacts reserves quantity.

Recap

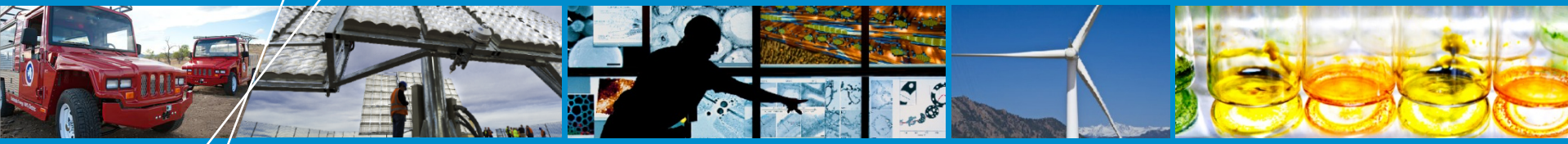
- Why these three reforms?
- Are there really integration rates, or just practices that impact rates, terms, and conditions for ancillary services?

Contact and Questions

Got questions?

Aaron.Bloom@nrel.gov

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



Are Integration Costs and Tariffs Based on Cost-Causation?

Michael Milligan, NREL

About This Presentation

Most information in this presentation is taken from:

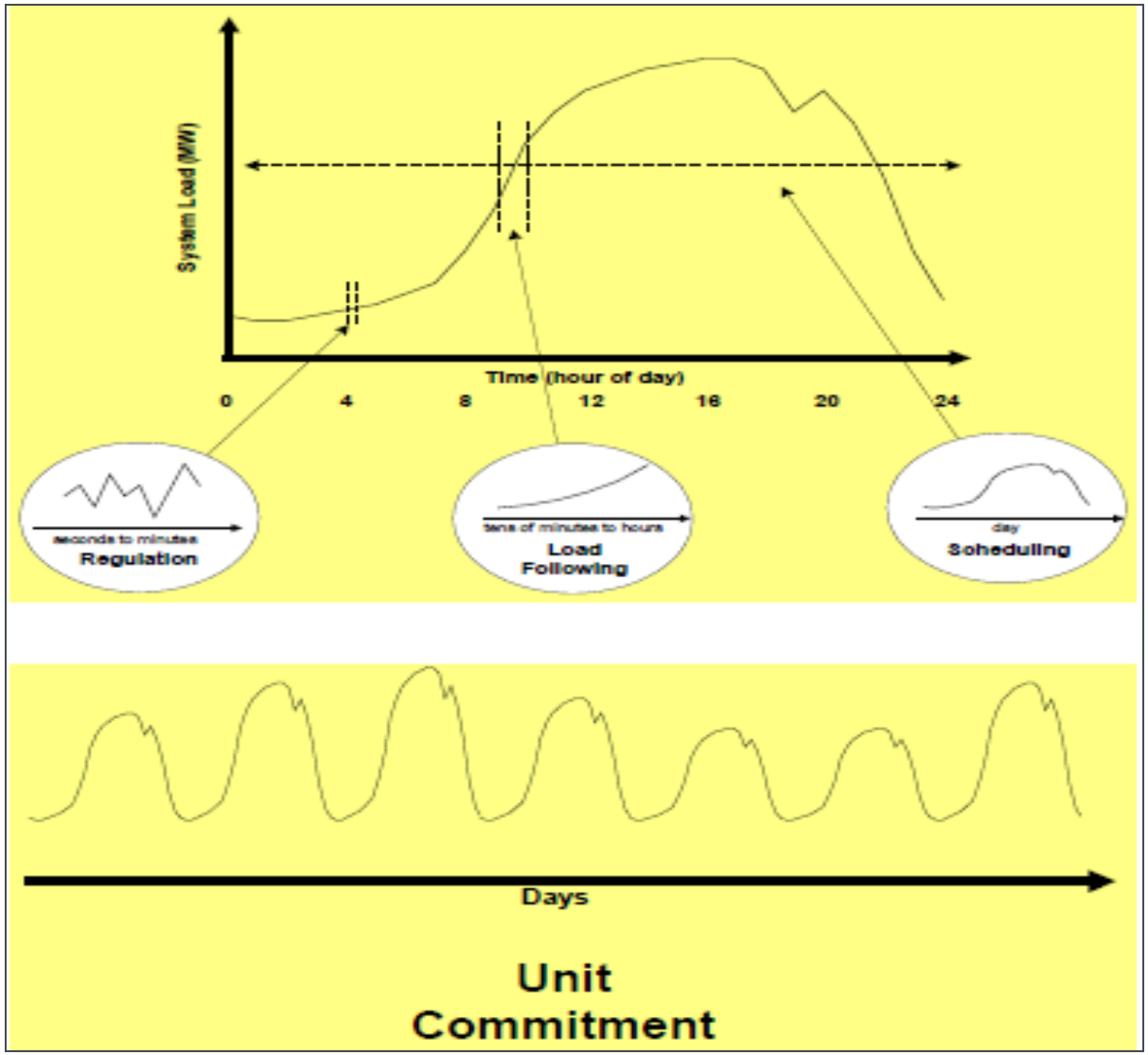
***Cost-Causation and Integration Cost Analysis for Variable Generation*. Milligan, M.; Ela, E.; Hodge, B. M.; Kirby, B.; Lew, D.; Clark, C.; DeCesaro, J.; Lynn, K.**

http://www.nrel.gov/docs/fy11osti/51860.pdf

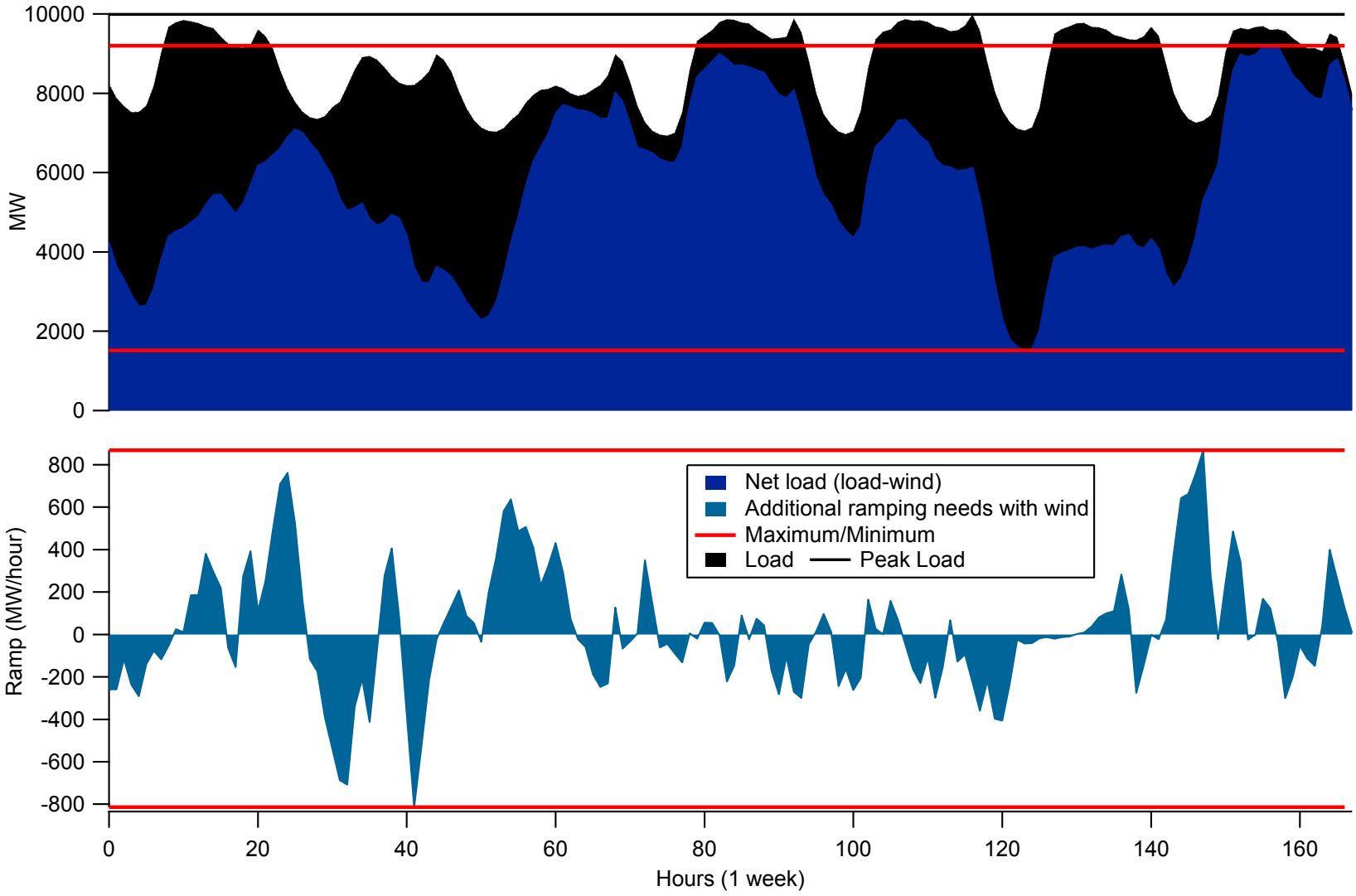
Outline/Headlines

- Integration costs are difficult to calculate.
- Other types of generation can impose integration costs
- Technology or performance-based integration cost?

Time Scale for Power System Operation



Additional Ramping/Range → More Flexibility

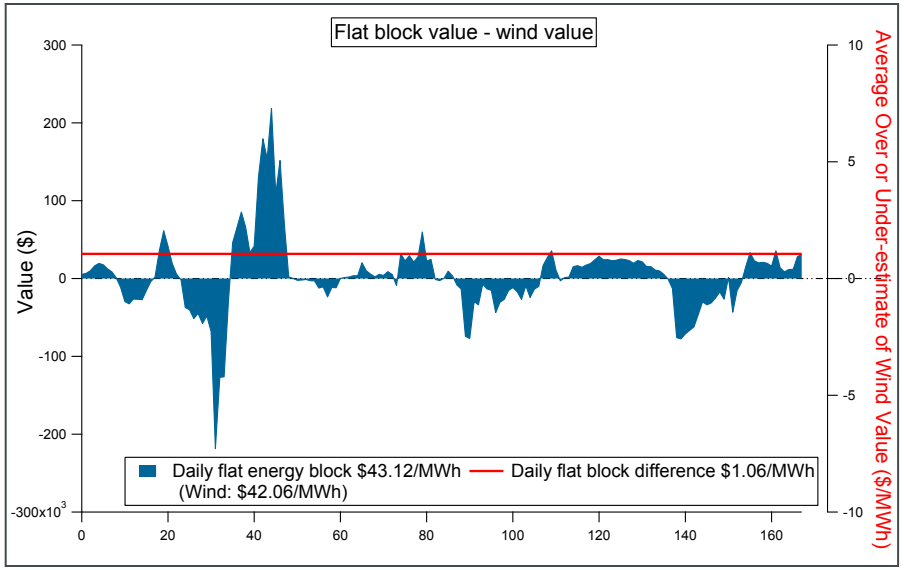


Integration Costs: Wind and Solar

- Wind and solar generation increase variability and uncertainty in power systems operation.
- Solar and wind integration issues are similar.
- Cycling efficiency and flexibility reserves are key components.
- Integration costs are not unique to wind or solar.

How Are Integration Costs Calculated?

- **Compare two (or more) alternative simulations of the power system using production simulation/cost models.**
  - With wind/solar
  - Without wind/solar
- **To provide an energy-equivalent basis, a hypothetical unit is often chosen for the "without wind/solar" case.**
- **This proxy resource may introduce unintended consequences.**
- ***It is natural to ask about integration costs, but extremely difficult, if not impossible, to measure them accurately.***



Total System Costs or Integration Costs

- **Total operating costs are relatively easy to calculate.**
- **Integration costs are difficult to calculate correctly.**
- **Both of these are sensitive to assumptions about other parts of the power system.**
  - What is the mix of conventional generation?
  - What is the transmission build-out (if any)?
  - What are the institutional constraints?
  - What is the electrical footprint?
  - Do markets allow access to physical capability that exists, or is this access constrained?
  - What will the power system look like in 20xx?

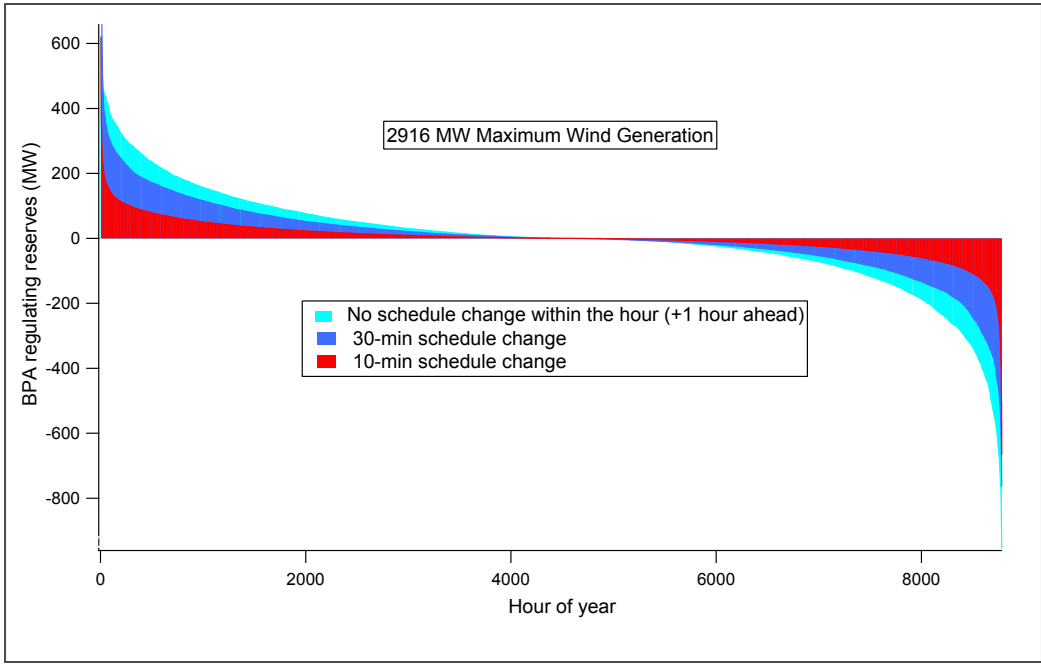
Integration Costs and Cost-Causation

- **Principles of cost-causation (see report)**
- **Cost-causer: must cause the cost**
  - If cost-causer is removed, so is the cost
  - If costs change, then agent of change is responsible
  - May be difficult to untangle

Are there other sources of integration costs?

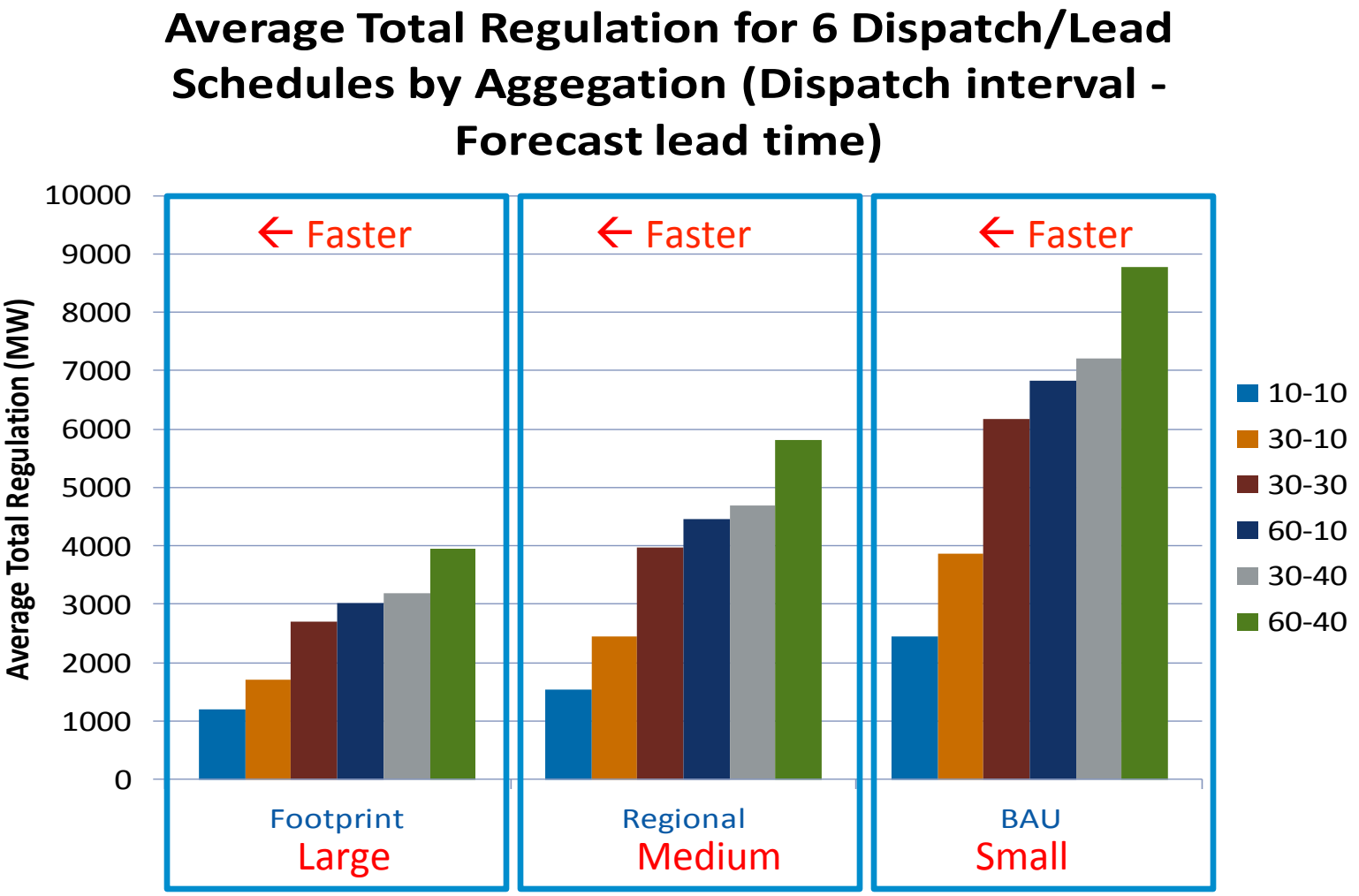
Sources of Integration Cost: Scheduling/Dispatch

- **Hourly block schedules**
  - Impact of hourly schedules on BPA wind exports
  - California Intermittency Analysis Project/GE, 2007
  - NREL's Western Wind and Solar Integration Study, 2010
- **Contingency reserves**
- **New low-cost baseload**
- **Conventional generators (thermal) that don't follow automatic generation control signal**



Milligan, Kirby, King, Beuning (2011). "The Impact of Alternative Dispatch Intervals on Operating Reserve Requirements for Variable Generation." Presented at the 10th International Workshop on Large-Scale Integration of Wind (and Solar) Power into Power Systems, Aarhus, Denmark. October 2011.

Small Balancing Authorities and Scheduling Intervals Impose Integration Costs

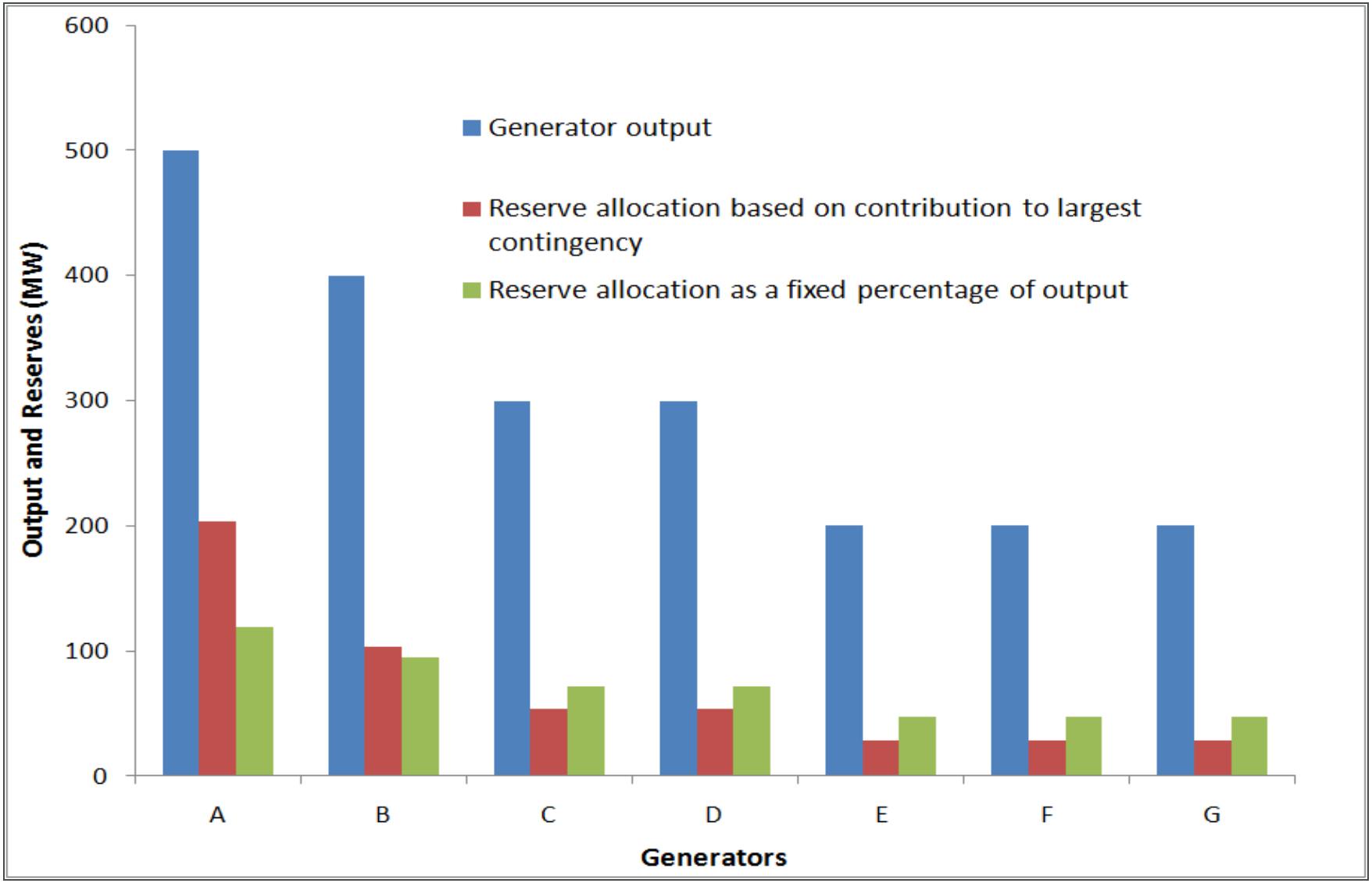


Milligan, Kirby, King, Beuning (2011). "The Impact of Alternative Dispatch Intervals on Operating Reserve Requirements for Variable Generation." Presented at the 10th International Workshop on Large-Scale Integration of Wind (and Solar) Power into Power Systems, Aarhus, Denmark. October 2011.

Contingency Reserves

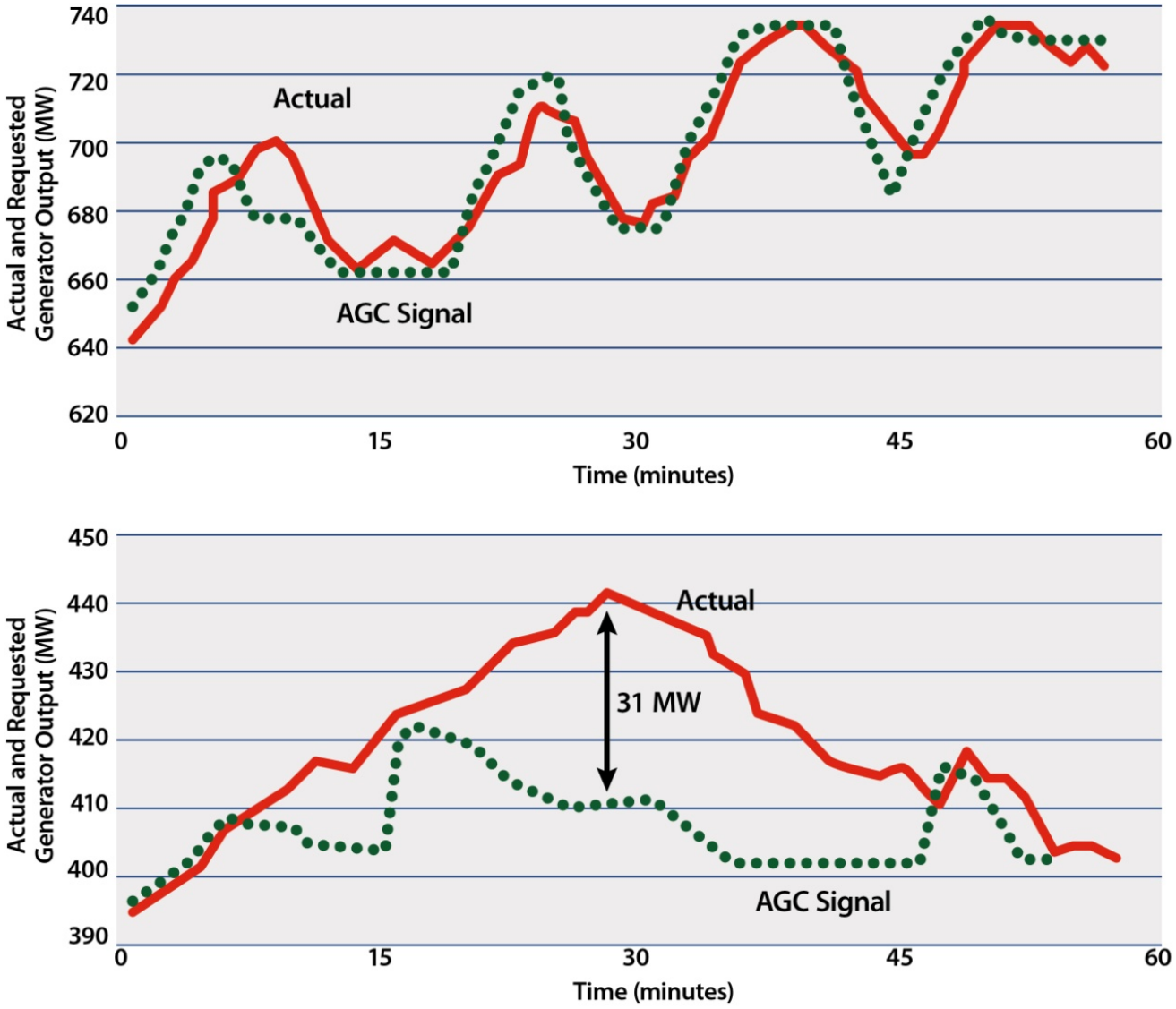
- **Specific rules vary, but the contingency reserve is typically set by the largest unit in the pool.**
- **Often, the specific reserve allocation is based on load ratio share or another similar metric.**
- **When the largest unit is replaced by a still larger unit, contingency reserve obligations increase.**
- **→ *If I am a generation owner/operator, I will find my contingency reserve obligation may increase independently of any action I have taken (or not taken).***

Contingency Reserve Costs Could Be Allocated by Generator Contribution to Contingency Reserve Activation … But This Is Not Done



Conventional Units May Impose Regulation Costs

Two similar coal-fired generators are both trying to provide regulation. The upper generator is following dispatch instructions fairly well and providing regulation, but the lower generator is not and is imposing a regulation burden on the power system.

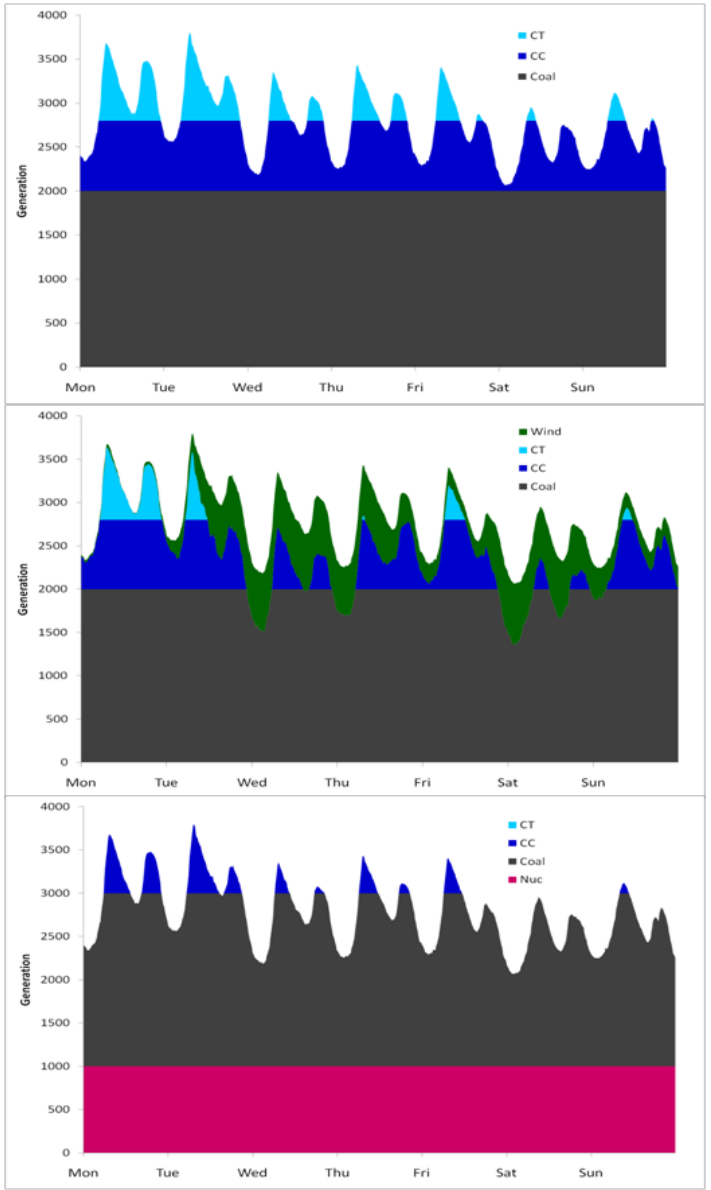


New, Low-Cost Baseload May Cause Integration Costs

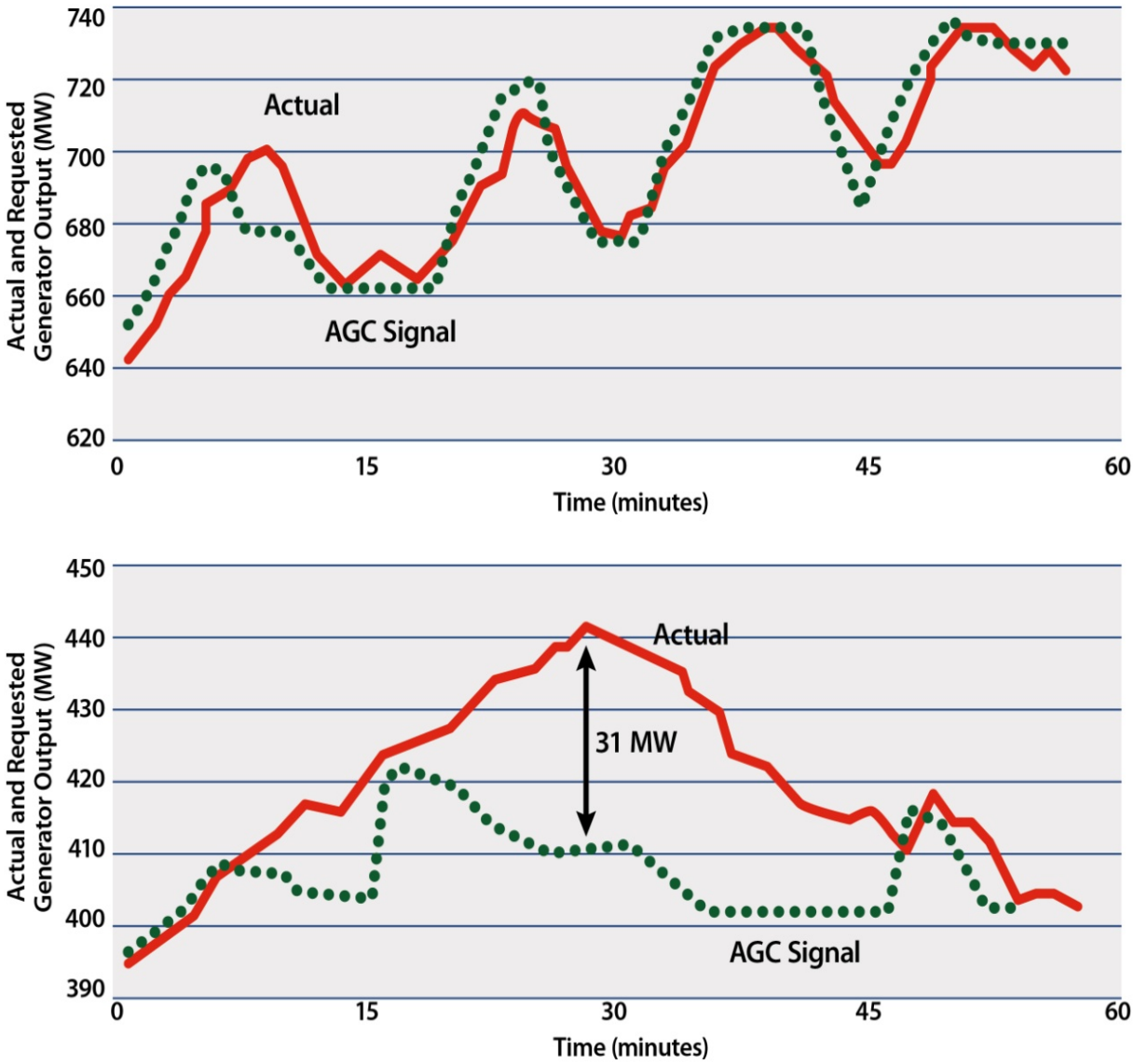
1. Coal is operated as baseload unit.

2. With new wind generation added, gas and coal cycling increase and capacity factors decline.

3. Instead of adding wind, a new, cheap baseload technology is introduced. Coal cycling increases; gas is nearly pushed out. Both coal and gas have lower capacity factors.



Performance Metric Versus Generation Type



Summary

- Wind (and solar) integration costs are very difficult to calculate correctly.
- Other technologies can impose integration costs.
- → If integration costs are to be assessed, a performance-based metric would be more appropriate … or perhaps none at all.

Questions?